A Natura 2000 Monitoring Framework – Using Plant Species Gradients for Spectral Habitat Assessment

Carsten Neumann[1], Gabriele Weiss[2], Sibylle Itzerott[1]

[1]Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam
Email: {carstenn; itzerott}@gfz-potsdam.de

[2]ecostrat GmbH, Marschnerstr. 10, 12203 Berlin
Email: gabriele.weiss@ecostrat.de

1. Introduction

Natural habitats are multidimensional environmental spaces with characteristic ecological gradient compositions. Remote sensing often decomposes complex habitat configurations in order to find distinct spectral coherence for mapping approach. For habitat quality assessment, ecological relevant parameters are commonly defined a priori. As a result habitat features are often described and mapped as plant community or biotope classes (Kerr & Ostrovsky 2003, Xie et al. 2008) or multi species indicator approaches (Bock et al. 2005). Consequently, discrete habitat maps can only represent reduced aggregates of species environment. First promising approaches to describe habitats as ecological continua with hyperspectral reflectance signatures were achieved in heathlands and moist meadow areas (e.g. Trodd 1996, Schmidtlein et al. 2007). It was shown that reflectance signatures can predict continuous floristic transitions that are projected to an ordination space. However, the assessment potential by ordinated parameter aggregation for habitat type monitoring still remains unsolved in application.

Under the legal framework of the European Natura 2000 network habitat type and status has to be assessed and reported for large areas. In our study we developed a monitoring framework for an area-wide mapping of FFH habitat types and related assessment categories, using environmental space gradients. Therein homogenous as well as ecotone areas were modelled by means of plant species ordination. Based on ordination topology we introduce predictive aggregation techniques on habitat quality parameter for floristic and faunistic suitability indicators. It shall be demonstrated that habitat status can be assessed by ecological gradients that are translated to occurrence probabilities for habitat types and species, simultaneously. We can further prove significant relations on spectral variables to ordination dimension for a spatially explicit monitoring with hyperspectral imagery.

2. Conceptual Monitoring Framework

In Figure 1 the methodological framework for the spatially explicit derivation of FFH habitat parameters used for assessment is presented. On the basis of plant species assemblages a habitat assessment can be realized in an environmental continuum forming floristic composition or faunistic distribution pattern. We propose non variance explaining axes projection such as non-metric multidimensional scaling (NMDS) (Kruskal 19964) as ordination technique in order to project species variability into two or three dimensions for visualization. Plant cover values have to be collected over the whole range of habitats and transitions that are likely to occur in the study area. In order to find appropriate sample size, ordinated plot topology is tested on pattern significance and configuration stability (Pillar 1999). Ordination axes are subsequently modelled with spectral variables derived for field plots using Partial Least Squares Regression (PLSR) (Wold, 1966). Distinct spectral features for gradient description are extracted within axes models and finally used to transfer axes scores to image spectra.

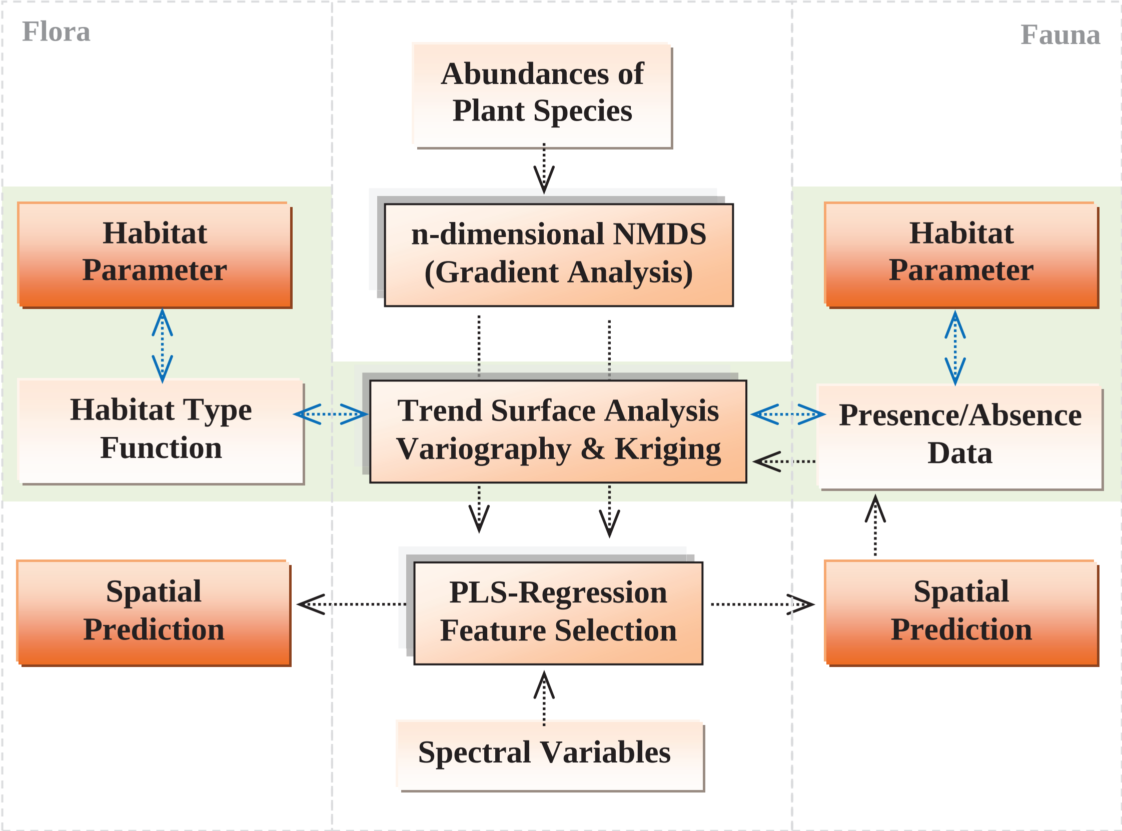

Figure 1: Conceptual framework for a remote sensing based monitoring of natural habitats using environmental space aggregation

The central embedding for habitat assessment is set in between ecological and spectral modelling approaches (Figure 1, green). It generates information for species distribution along abstract gradients and score values, respectively. Thereby floristic habitats can be described by plant species compositions that are aggregated under consideration of functional relations. Habitat type functions translate species complexes to type specific occurrence probabilities. Therein, single types or corresponding encroachments are defined over species occurrences. Their cover values can be projected to ordinated plot configuration. Subsequently, trend surface analysis on axes coordinates in combination with geostatistical Kriging (Hengl et al. 2007) are applied for the spatial interpolation of habitat functions.

In addition ordination space areas for faunistic habitats can be determined on presence/absence data that are superimposed with spatially predicted score vales on field survey locations. Logistic trend surfaces followed by residual Kriging of Indicators are then used to interpolate probability spaces for faunal occurrence in environmental space. Furthermore, habitat quality parameter examination can be realised by relating environmental variables on ordinated field plots to predicted occurrence probabilities.

3. Example: FFH-Habitat Type and Status Mapping of Dry Grassland

A FFH-habitat assessment using proposed approach was realised on a former military training area, “Döberitzer Heide”, located at 53° latitude and 13° longitude west of Berlin, Germany. Long term military use created dry open grassland communities comprising FFH-Habitat types 2330 (Inland dunes with open Corynephorus and Agrostis grasslands), 4030

(European dry heath), and 6120 (Xeric sand calcareous grasslands) on glacial ground moraine deposits. After abandonment of military use in 1992, habitats increased in small scale floristic heterogeneity due to natural succession processes and active management (e.g. grazing mammals).

3.1 Data

The fractional cover of 98 different plant species were collected on 58 field plots within all FFH-habitat types and successional transitions. Plot size of 1 m² was set into a 5 m² floristic homogeneous surrounding in order to assure appropriate image pixel representation. A 2-dimensional NMDS was performed to project species variability into ordination space. Habitat type and habitat quality functions were derived by standardized sums of weighted plant species cover according Table 1. Habitat probability ranges from 0 to 1. For the spectral assessment the status of an FFH-habitat is combined by a reduced set of positive and negative habitat factors compared to terrestrial assessment. The results are aggregated to habitat status A (excellent), B (good), C (middle to bad).

Table 1: Selected plant species for FFH-Habitat type definition (+) and quality assessment (-); species were aggregated into habitat functions and projected to ordinated plot location

FFH 2330		**FFH 4030**		**FFH 6120**	
+	-	+	-	+	-
1*Corynephorus canescens	1*Agrostis capillaris	1*Calluna vulgaris	1*Sarothamnus scoparius	1*Festuca ovina agg.	1*Sarothamnus scoparius
1*Bare ground	1*Festuca ovina agg.		1*Populus tremula	1*Koeleria macrantha	1*Populus tremula
0.3*Spergularia morisonii	1*Deschampsia flexuosa		1*Festuca ovina agg.	1*Dianthus carthusianorum	1*Arrhenatherum elatius
0.3*Polytrichum piliferum	1*Calamagrostis epigeios		1*Deschampsia flexuosa	0.8*Achillea millefolium	1*Tanacetum vulgare
0.3*Cladonia spec.	1*Rubus caesius		1*Nardus stricta	0.2*Agrostis capillaris	1*Calamagrostis epigeios

Spectral models were calibrated on ordination axes scores using spectral reflectance signatures that were acquired with an ASD filed spectroradiometer during an AISA DUAL imaging spectrometer airplane overflight. Internal leave on out validation was used to select spectral variables and model accuracy assessment. In order to transfer spectral models to hyperspectral imagery an Empirical Line correction was performed on image spectra.

3.2 Results and Discussion

The occurrence probability for all three FFH-habitat types could be modelled with distinct pattern into ordination space (Figure 2). Transition between types, as well as inner type variability can be visualized in adjacent ecological gradients. Spectral variables can explain 89 % of first score axes variance with 3 latent components resulting in a Root Mean Squared Error of prediction RMSEP = 7,6 %. Second axes variability is represent to 75 % in selected spectral variables using 5 latent components (RMSEP = 11.6 %). In Figure 2 habitat type probabilities are spatially predicted on the basis of axes models. Habitat types are extracted for a Natura 2000 quality assessment according individual occurrence thresholds. Dry grasslands and heathland communities are spatially well separated with good habitat status in core areas. In contrast, LRT 6120 show a widely spread distribution with mostly degraded habitat characteristics. They often exist within transition to heathland.

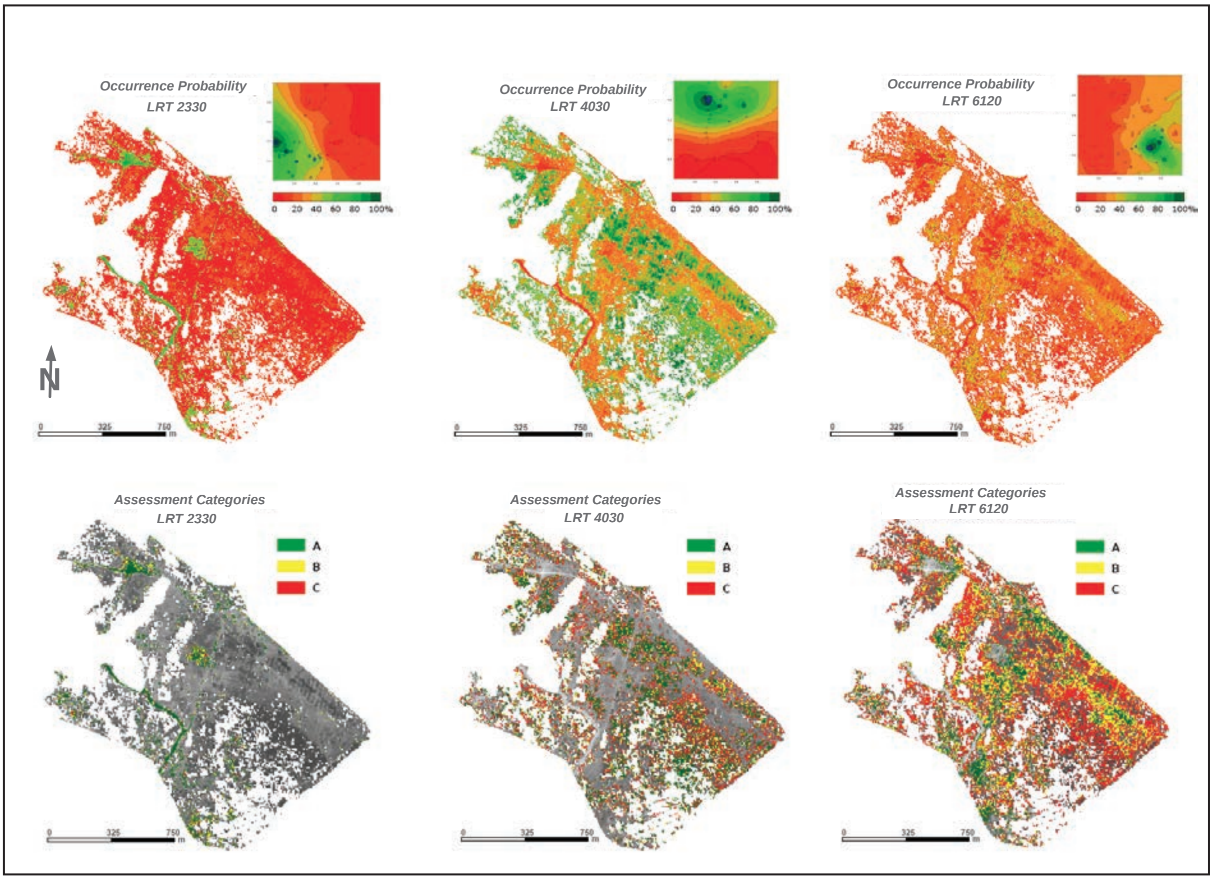

Figure 2: Spatial representation of ordinated FFH-habitat type occurrence probabilities and assessment categories

An external validation were performed on species transect comprising transitions between all three habitat types. In total the fractional cover of character species on 23 plots was correlated to habitat type probability. Calluna vulgaris was well correlated to LRT 4030 with $R^2 = 0.85$. LRT 2330 is mainly correlated to Corynephorus canescens ($R^2 = 0.79$) and bare ground ($R^2 = 0.84$). Xeric grasslands (LRT 6120) are more complex in species composition. Best correlation can be achieved with Festuca ovina agg. ($R^2 = 0.61$). It can be concluded that species rich environments are more difficult to aggregate in ordination spaces with regard to distinct parameter separation. Hence, a spectral monitoring must be reduced to highly diagnostic species concern spectral and ecological separable gradients.

4. Outlook

The proposed Natura 2000 monitoring approach can be further developed on different habitat type definitions (e.g. biotope, EUNIS). Its transferability to different landscapes should be assessed. Thereby its applicability on automated spectral library information extraction for hyperspectral imagery in varying phenological phases has to be tested.

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